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CONFERENCE ON INTERNATIONAL SCIENTIFIC DEVELOPMENTS: INSIGHTS INTO MODERN SCIENCE AND INNOVATIVE PRACTICES

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AGENTLI SUN'IY INTELLEKT TIZIMLARIDA AXBOROT OQIMI XAVFSIZLIGIGA TAHDIDLAR TASNIFI VA HIMOYALASH USULLARINING QIYOSIY TAHLILI

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Kalit so'zlar:
agentli sun'iy intellekt, katta til modellari, axborot oqimini nazorat qilish, bilvosita prompt-in'eksiya, maxfiylik, yaxlitlik, noaralashuv, Model Context Protocol.

Annotatsiya. Tezisda katta til modellariga (LLM) asoslangan agentli sun'iy intellekt tizimlarida axborot oqimi xavfsizligi muammosi tahlil qilingan. Bilvosita prompt-in'eksiya hujumlari axborot oqimini nazorat qilish (IFC) nazariyasi nuqtai nazaridan maxfiylik va yaxlitlik xossalarining buzilishi sifatida talqin etilgan. Tahdidlarni kirish manbai, buzilgan xossa va oqim turi bo'yicha tasniflovchi uch o'lchovli sxema taklif qilingan. Model darajasidagi ehtimoliy va arxitektura darajasidagi deterministik himoyalash usullari (Dual LLM, f-secure, CaMeL, FIDES, APPA) to'rt mezon asosida qiyosiy tahlil qilingan. Belgilarning «shishishi» bilan bog'liq xavfsizlik va funksionallik o'rtasidagi murosa asosiy ochiq muammo sifatida asoslangan.

Ключевые слова:
агентный искусственный интеллект, большие языковые модели, контроль информационных потоков, косвенная промпт-инъекция, конфиденциальность, целостность, невмешательство, Model Context Protocol.

Аннотация. В тезисе рассматривается проблема безопасности информационных потоков в агентных системах искусственного интеллекта на основе больших языковых моделей (LLM). Атаки косвенной промпт-инъекции интерпретируются с позиций теории контроля информационных потоков (IFC) как нарушение свойств конфиденциальности и целостности. Предложена трёхмерная схема классификации угроз по источнику данных, нарушаемому свойству и типу потока. Проведён сравнительный анализ вероятностных методов защиты на уровне модели и детерминированных архитектурных методов (Dual LLM, f-secure, CaMeL, FIDES, APPA) по четырём критериям. Обосновано, что ключевой открытой проблемой является компромисс между безопасностью и

функциональностью, обусловленный «разрастанием» меток.

KIRISH

So‘nggi yillarda katta til modellari mustaqil harakat qiluvchi agentlarga aylanmoqda: agent topshiriqni rejalashtiradi, tashqi vositalarni chaqiradi, xotiraga ega bo‘ladi va boshqa agentlar bilan o‘zaro ishlaydi, Model Context Protocol (MCP) esa ularni korporativ tizimlarga ulashni standartlashtirmoqda. O‘zbekistonda tasdiqlangan sun’iy intellekt texnologiyalarini 2030-yilga qadar rivojlantirish strategiyasida davlat xizmatlari portalida SI asosidagi xizmatlar ulushini 10 foizga yetkazish ko‘zda tutilgan [2]. Bu SI agentlari xavfsizligini «Kiberxavfsizlik to‘g‘risida»gi Qonun [1] talablari doirasida tadqiq etishni taqozo etadi.

Agentli tizimlarning asosiy zaifligi shundaki, LLM buyruq va ma’lumotni yagona kanal – kontekst oynasi orqali qabul qiladi va ularni ishonchli farqlay olmaydi. Natijada agent qayta ishlayotgan veb-sahifa, xat yoki hujjatga yashirilgan ko‘rsatma uning xatti-harakatini o‘zgartiradi (bilvosita prompt-in’eksiya [3]). Masalan, EchoLeak zaifligida maxsus tuzilgan elektron xat foydalanuvchining hech qanday harakatisiz Microsoft 365 Copilot orqali maxfiy ma’lumotlarni tashqariga chiqarish imkonini bergan [4]. OWASP’ning agentli ilovalar xavflari ro‘yxatida ham agent maqsadini egallab olish birinchi o‘rinda turadi [5].

Tadqiqot ishining maqsadi – agentli SI tizimlarida axborot oqimi xavfsizligiga tahdidlarni tizimlashtirish va himoyalash usullarini yagona mezonlar asosida qiyosiy baholash. «Axborot oqimi xavfsizligi» bu yerda tarmoq trafigini himoyalash ma’nosida emas, balki axborot oqimini nazorat qilish nazariyasi ma’nosida – ma’lumotlarga biriktirilgan maxfiylik va yaxlitlik belgilarining tizim komponentlari orasida tarqalishini nazorat qilish sifatida tushuniladi [6, 7].

ASOSIY QISM

1. Muammoning formal qo‘yilishi. Agentli tizimni $A = \langle U, P, T, M, E \rangle$ ko‘rinishida ifodalaymiz: U – foydalanuvchi (ishonchli buyruq manbai), P – rejalovchi LLM, T – vositalar, M – xotira, E – tashqi muhit. Har bir ma’lumot x ga $\ell(x) = (c, i)$ belgisi biriktiriladi, bu yerda $c \in \{\text{Ochiq} \sqsubseteq \text{Maxfiy}\}$, $i \in \{\text{Ishonchli} \sqsubseteq \text{Ishonchsiz}\}$. Belgilar to‘plami $\sqcup$ birlashma amali bilan panjara hosil qiladi va x dan y ga oqimga faqat $\ell(x) \sqsubseteq \ell(y)$ bo‘lganda ruxsat beriladi [6]. Xavfsizlik ikki shart bilan ifodalanadi: (1) yaxlitlik – tashqi ta’sirga ega $t \in T$ vositasi faqat uni chaqirish qarori va argumentlari «Ishonchli» bo‘lganda bajariladi; (2) maxfiylik – x ma’lumoti s chiqish nuqtasiga (xat oluvchi, URL, tashqi API) faqat $c(x) \sqsubseteq c(s)$ bo‘lganda uzatiladi. Bu shartlar Goguen–Meseguer noaralashuv xossasining [7] agentlar uchun amaliy shaklidir.

Muammoning o‘zagi shundaki, LLM «qora quti» bo‘lib, uning chiqishi butun kontekstga bog‘liq. Shu sababli konservativ baholashda $\ell(P(ctx)) = \sqcup\ \ell(x)$, $x \in ctx$ bo‘ladi: kontekstga bitta ishonchsiz element kirishi bilan keyingi barcha qarorlar «Ishonchsiz» deb belgilanadi. Bu hodisa belgilarning «shishishi» deb ataladi va IFC ni agentlarga qo‘llashdagi asosiy to‘siqdir. Agent bir vaqtda maxfiy ma’lumotga kirish, ishonchsiz kontentni qayta ishlash va tashqi aloqa imkoniyatiga ega bo‘lsa, ma’lumot oqib chiqishi uchun barcha shartlar jamlanadi («halokatli uchlik» [8]).

2. Tahdidlar tasnifi. OWASP ro‘yxati [5], AgentDojo test to‘plami [9] va ilmiy manbalarni umumlashtirib, tahdidlarni uch o‘lchov bo‘yicha tasniflash taklif etiladi:

- K1 (kirish manbai): tashqi kontent (veb-sahifa, xat, hujjat, RAG bazasi); MCP vositalarining tavsiflari va javoblari; agent xotirasi; boshqa agentlar xabarlari;
- K2 (buzilgan xossa): yaxlitlik (maqsadni egallab olish, ruxsatsiz harakat); maxfiylik (ma’lumotni oqizib chiqarish); ikkalasi birga – «chalkash vakil» (confused deputy);
- K3 (oqim turi): aniq (ma’lumot vosita argumentiga bevosita ko‘chadi); yashirin (vosita tanlovi, tarmoqlanish yoki chaqiruvlar soni orqali); tranzitiv (xotira yoki boshqa agent orqali kechiktirilib, boshqa sessiyada namoyon bo‘ladi).

Tasnif har bir K1×K2×K3 katagi uchun kafolat beruvchi himoya mexanizmini aniqlashga xizmat qiladi. Masalan, EchoLeak «tashqi kontent × maxfiylik × aniq oqim» sinfiga, xotiraga yozilgan zararli ko‘rsatmaning keyingi sessiyada ruxsatsiz harakatga sabab bo‘lishi esa «xotira × yaxlitlik × tranzitiv oqim» sinfiga mansub.

3. Himoyalash usullarining qiyosiy tahlili. Model darajasidagi usullar – ishonchsiz ma’lumotni ajratib belgilash [10], ko‘rsatmalar ierarxiyasiga o‘qitish, in’eksiyani aniqlovchi klassifikatorlar – funksionallikka deyarli ta’sir qilmaydi, biroq ehtimoliy bo‘lib, adaptiv hujumlar bilan chetlab o‘tilishi mumkin. Arxitektura darajasidagi deterministik usullar esa LLM zaif bo‘lsa ham xavfsizlikni tizim darajasida ta’minlaydi (1-jadval).

1-jadval. Agentli tizimlarda axborot oqimini himoyalash usullarining qiyosiy tahlili

Usul	Kafolat turi	Nazorat nuqtasi	Funksional-likka ta’siri	Asosiy cheklov
Model darajasidagi usullar [10]	Ehtimoliy	Model kirishi va chiqishi	Deyarli yo‘q	Adaptiv hujumlarga bardoshsiz

Usul	Kafolat turi	Nazorat nuqtasi	Funksional-likka ta’siri	Asosiy cheklov
Dual LLM [11]	Boshqaruv oqimi yaxlitligi (izolyatsiya)	Imtiyozli va karantindagi LLM chegarasi	Sezilarli	Vosita argumentlari orqali oqim nazoratsiz
f-secure [12]	Deterministik, formal modelga asoslangan	Rejalashtirishga kirishni filtrlovchi monitor	Mualliflarga ko‘ra saqlanadi	Ishonchsiz ma’lumotga bog‘liq rejalashtirish cheklangan
CaMeL [13]	Deterministik: boshqaruv oqimi + capability	Maxsus interpretator	AgentDojo’da 84% → 77%	Siyosatlarni qo‘lda yozish; yon kanallar
FIDES [14]	Deterministik: maxfiylik va yaxlitlik belgilari	Rejalovchi va siyosat mexanizmi	Oddiy siyosatli rejalovchidan yuqori	LLM qobiliyatiga bog‘liq; maxfiy ma’lumot boshqaruv qarorlariga ta’sir qilishi mumkin
APPA [15]	Deterministik monitor + tiklash	Vosita chaqiruvi va MCP shlyuzi, ikki bosqichli	64,2–91%; 1320 epizodda hujum kuzatilmagan	Yangi yondashuv, mustaqil tekshiruv yo‘q

Deterministik usullar kafolat evaziga funksionallikni pasaytiradi, bunga belgilarning «shishishi» sabab bo‘ladi. Rivojlanish yo‘nalishi aniq: qat’iy izolyatsiyadan boshqaruv oqimini dasturiy ajratishga, nozik belgilar va ma’lumotni tanlab yashirishga, so‘ng bloklash o‘rniga siyosat asosida tiklashga. Biroq tranzitiv oqimlar faqat qisman qamraladi: belgilar odatda bitta sessiya yoki ish oqimi doirasida kuzatiladi.

XULOSA

1. Bilvosita prompt-in’eksiya mohiyatan axborot oqimi muammosidir; uni model darajasidagi ehtimoliy usullar bilan to‘liq hal etib bo‘lmaydi, kafolatli himoya IFC tamoyillariga asoslangan arxitektura yechimlarini talab qiladi.

2. Taklif etilgan uch o‘lchovli tasnif tahdidlar va himoya mexanizmlarini yagona tizimda moslashtirish hamda himoyalanmagan tahdid sinflarini aniqlash imkonini beradi.
3. Asosiy ochiq muammolar: belgilarning «shishishi» tufayli funksionallik pasayishi; LLM qarorlari orqali yashirin oqimlar; belgini pasaytirish (deklassifikatsiya) qarorlarining asoslanganligi; xotira va ko‘p agentli tizimlarda belgilarning sessiyalararo tarqalishi.
4. Davlat axborot tizimlari va muhim axborot infratuzilmasi obyektlarida «halokatli uchlik»ni bitta agentda birlashtirmaslik hamda vosita chaqiruvlarini deterministik siyosat bilan nazorat qilishni majburiy talab sifatida belgilash tavsiya etiladi.

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